JOINT INSTITUTE FOR ADVANCEMENT OF FLIGHT SCIENCES

Program of Research in Flight Dynamics in the JIAFS at NASA-Langley Research Center

NASA Cooperative Agreement NCC1-29

Annual Status Report

December 1, 1991 - November 30, 1992

School of Engineering and Applied Science
The George Washington University
Washington, DC 20052

OVERVIEW

The program objectives are fully defined in the original proposal entitled "Program of Research in Flight Dynamics in the JIAFS at NASA-Langley Research Center," which was originated March 20, 1975 and in the renewal of the research program dated December 1, 1991.

The program in its present form includes four major topics:

1. The improvement of existing methods and development of new methods for flight test data analysis,

2. the application of these methods to real flight test data obtained from advanced airplanes,

3. the correlation of flight results with wind tunnel measurements, and

4. the modeling, and control of aircraft, space structures and spacecraft.

The Principal Investigator of the program is Dr. V. Klein. Five Graduate Research Scholar Assistants (K. D. Noderer, V. N. Iannacci, A. Kokolios, E. N. Johnson and M. D. Cavanaugh) also participate in the program. In August 1992 one of the Assistants (V. N. Iannacci) completed the requirements of the Master of Science degree and two new Assistants (J. W. Gloystein and B. D. Taft) joined the program.

SPECIFIC DEVELOPMENTS

Specific developments in the program during the period December 1, 1991 through November 30, 1992 included:

1. Research on methods for system identification. The algorithm for data collinearity diagnostic and two biased

estimation techniques developed for the linear regression was applied to data from testing the X-31 drop model and X-29 aircraft at moderate to high angles of attack. As in the previous applications it was found that the fractional rank regression is very sensitive to the rank reduction of the information matrix. A set of simulation experiments was used for investigating the optimal rank reduction and its effect on the accuracy of estimated parameters. The collinearity diagnostic and biased estimation techniques were expanded to the maximum likelihood estimation method. A draft of the final report has been prepared.

2. Application of system identification to advanced high-performance aircraft. The main effort was concentrated on the X-31 drop model experiment. Lateral aerodynamic parameters of the model were estimated from flight data at angles of attack between 25° and 45°. Partitioned data from an ensemble of 12 maneuvers and data from 13 single maneuvers were analyzed by a stepwise regression technique to obtain an aerodynamic model structure and least squares parameter estimates. Because of data collinearity in several maneuvers, these maneuvers were reanalyzed by two biased estimation techniques, mixed estimation and fractional rank regression. The final parameter estimates in the form of stability and control derivatives were compared with wind tunnel results and a limited number of estimates from full-scale aircraft data. There was no significant disagreement between parameters from the two sets of drop model data and the full-scale aircraft data. Some differences, however, exist

between the dihedral, damping-in-roll, and aileron-effectiveness parameters from flight and wind tunnel data. The program continues with the additional flights for obtaining lateral and longitudinal parameters of the model with fuselage strakes installed.

Flight test data of the X-29 aircraft have been analyzed for obtaining longitudinal stability and control derivatives. A final report on the estimation of X-29 aerodynamic parameters from flight data is under preparation.

3. Control design for agile aircraft. Three methods for choosing closed loop eigenvectors in the eigenspace assignment control law synthesis technique were investigated. Numerous linear models of the aircraft dynamics were generated and several nonlinear simulations of the HARV were performed for testing control law designs. In addition to simulation, a series of control theory tools were used to evaluate control law designs. For the automation of the evaluation processes, several software programs were written or upgraded.

4. Optimal control of a spacecraft. One research assistant participated in the software development for the variational trajectory optimization. This software has been used for obtaining the on-line guidance of an aerobrake vehicle through a variable density atmosphere. A report including stochastic aerobrake trajectory, model of the atmosphere using density measurements, and the implementation of optimal trajectory in an aerobrake simulation code is under preparation.

PUBLICATIONS

1. V. Klein and K. D. Noderer, "Aerodynamic Parameters of the X-31 Drop Model Estimated From Flight Data at High Angles of Attack," AIAA Paper 92-4357-CP, August 1992.

2. K. D. Noderer, "Analysis of the Lateral Aerodynamic Characteristics of the X-31 Drop Model Obtained from Flight Test Data," Master of Science Thesis, The George Washington University, July 1992.

3. V. N. Iannacci, "A Comparison of Three Methods for Choosing Closed Loop Eigenvectors Used in the Eigenspace Assignment Flight Control Law Synthesis Procedure," Master of Science Thesis, The George Washington University, July 1992.

4. E. N. Johnson (co-author), "HARV NASA-1 Control Law Specification," Internal NASA Document, September 1992.

5. M. D. Cavanaugh (co-author), "Variational Trajectory Optimization," NASA TM (in print).

PRESENTATIONS (V. Klein)

1. "An Outline of System Identification and its Application to an Aircraft Operating in High Angles of Attack Flight Regimes."

2. "Aircraft Parameter Estimation From Highly Correlated Flight Data," University of Glasgow, Great Britain, May 26 and 27, 1992. DLR Inst. of Flight Mechanics, Braunschweig, Germany, June 9 and 10, 1992.

OTHER ACTIVITIES (V. Klein)

1. Consultant mission to discuss "System Identification Applied to Aircraft at Critical Flight Regimes," at the Glasgow University, Glasgow, Great Britain, May 26-29, 1992, and the German Institute for Aeronautics and Astronautics (DLR), Braunschweig, Germany, June 9-12, 1992, at the invitation of the NATO Advisory Group for Aerospace Research and Development (AGARD).

2. Critical review of

   a. a draft of AGARDograph prepared by J. M. Mulder et al from Delft University and the National Aerospace Laboratory, The Netherlands;

   b. a thesis submitted for a PhD degree at the Indian Institute of Science, Bangalore, India.

3. Review of six papers submitted for publication in the Journal of Aircraft.